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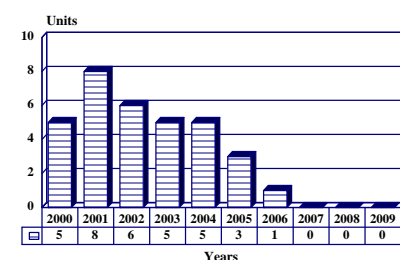
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Turbomeca TM-1600 I&M - Archived 12/2001

Outlook

- Outlook is for limited orders in the power generation/cogeneration arena
- Machine popularity expected to remain for mechanical drive duty into mid-decade

10 Year Unit Production Forecast
2000 - 2009



Orientation

Description. The TM-1600 is a two-shaft, axial-centrifugal-flow, aero-derivative industrial and marine gas turbine machine in the 1.0-1.5 MW class.

*The designations TM-1600 and TM-1600 Industrial & Marine (or TM-1600 I&M) are used interchangeably. This report adheres to the designation **TM-1600 I&M**, and covers the TM-1600 Industrial and Marine version only. The TM-1600 I&M machine is also known as the Makila TI, a derivative of the Makila aero-engine line (the letters "TI" stand for "Turbine Industriel").*

Sponsor. The Turbomeca TM-1600 I&M was privately developed by the prime manufacturer.

Contractors. The prime manufacturer is Turbomeca, Land and Marine Turbines; Bordes, Bizanos, France (Turbomeca is a subsidiary of Groupe Labinal).

Packagers. Recent and current packagers of the TM-1600 I&M include:

- Allen Industries Incorporated; Seattle, Washington, USA.
- Ishikawajima-Harima Heavy Industries Company Limited (IHI); Tokyo, Japan.

Power Class. The ISO baseload power rating is approximately 1,120 kW (1,500 hp).

Status. In production.

Total Produced. As of the end of 2000, an estimated 100 TM-1600 I&M/Makila TI I&M machines are projected to have been built (including units for testing) for electrical generation, mechanical drive and marine duty. That total *does not* include units built for train/rail applications. (Through 1999, a total of 95 I&M machines are estimated to have been built).

Application. Electrical generation/cogeneration; mechanical drives, including pumping and compression; marine propulsion.

Price Range. Estimated at \$950,000-\$1.1 million in 2000 US dollars for a production-standard, machine-equipped gas turbine generating package, including gas turbine machine, generator, skid and enclosure, ducts, silencers, and controls/accessories. Approximate price of an unmounted TM-1600 is \$750,000-\$850,000.

Competition. In the power generation arena, the main gas turbine machine that most actively compete against the TM-1600 I&M are the Solar Saturn 20, Dresser-Rand KG2-3C and Kawasaki M1A-03 and M1A-13A. In the mechanical drive arena, the main gas turbine machine that most actively compete against the

TM-1600 I&M are the Saturn 20 and Pratt & Whitney Canada ST6L-813.

Technical Data

Design Features. Design features of the Turbomeca TM-1600 I&M machine include the following:

Intake. Annular pitot type with bulletdome spinner. Hot air anti-icing.

Compressor. Three-stage axial compressor and single-stage centrifugal unit provide a pressure ratio of 9.9:1. Axial stages are of forged titanium, while the centrifugal unit is machined from a steel forging. Stainless steel axial compressor nozzles. Stage 3 is an integrally cast component, consisting of a double ring of airfoils. Air flow is approximately 11.79 lb/sec (5.34 kg/sec).

Combustor. Single annular combustor. Fuel is injected into the combustor via a single centrifugal injector located in the shaft. Turbomeca injectors, ABG-SEMCA or EYQUEM ignition units with EYQUEM or Smiths igniters.

Compressor/Generator Turbine. Two-stage gas producer/compressor turbine, with separate uncooled blades, drives the gas generator at approximately 33,350 rpm. TIT is approximately 2,200°F (1,204°C). Gas producer turbine Stage 1-2 blades cast in MAR-M002.

Power Turbine. Two-stage PT drives the rear-mounted output shaft at 22,850 rpm (100 percent power turbine speed). PT blades are not tip-shrouded. Two nozzles are produced in HS 31 (X-40) cobalt-base alloy, and Stage 1-2 blades in MAR-M004 (IN713LC + Hf). PTO at 14,000-23,000 rpm.

Accessories. Top-mounted accessory gearbox driven via a shaft from the compressor rotor. Electric or pneumatic starting. The Digital Engine Control Unit (DECU) is derived from the ELECMA Full Authority Digital Electronic Control (FADEC). Industrial integrated reduction gear train with output power drive shaft with output speeds available at the following rpm settings: 22,850, 6,300, 6,000, 5,000, 3,600, 3,000, 1,800, and 1,500. Five borescopic inspection points are provided, as well as three magnetic plug oil inspection points.

Modular Construction. The TM-1600 I&M is designed for easy maintenance with modular construction. The five basic modules are: Auxiliary Gearbox, Axial Compressor, Gas Generator, Nozzle Guide Vane Segment, and Power Turbine Module.

Dimensions. Approximate dimensions of the TM-1600 I&M machine are as follows:

	<u>Metric Units</u>	<u>English Units</u>
Length	1.9 meters	74.8 inches
Width	0.8 meters	31.5 inches
Height	1.1 meters	43.3 inches
Weight		
Turbine Only	351 kg	775 pounds
With R1 Gearbox	440 kg	970 pounds
With R1 & R2 Gearboxes ^(a)	820 kg	1,807 pounds

^(a) Marine applications: turbine plus 1,500 rpm integral gearbox.

Performance. Approximate performance parameters of the TM-1600 I&M in a genset package are as follows (ISO conditions, no losses):

	<u>Metric Units</u>	<u>English Units</u>
Output Power	1,090 kW _e	1,460 hp
Fuel Consumption	13,122 kJ/kWh	12,436 Btu/kWh
Exhaust Temperature	500°C	932°F
Exhaust Flow	5.45 kg/sec	12.01 lb/sec

Variants/Upgrades

As of the end of 2000, no data or information was available to determine if any TM-1600 I&M variants had been produced or if any upgrade efforts had been formulated.

Program Review

Background. The Turbomeca TM-1600 I&M gas turbine machine (a.k.a. Makila TI) is an industrial and marine gas turbine variant of the popular Makila aviation turboshaft engine. Development of the machine began in 1975 to meet the expected demands for increased efficiency and power for aircraft applications of the 1980s. After 58 months of testing, the aviation Makila certification was awarded by the *Direction Generale a l'Aviation Civile* (DGAC) in April 1980. Work on series production turboshaft engines began in October 1979. Certification of the aviation Makila engine in the US is under FAA Type Certificate No. E12NE, issued April 13, 1981, and amended May 28, 1987 (for the 1A and 1A1).

Derived from the aero Makila, the TM-1600 I&M was designed for power generation (including cogeneration plants) and drive applications in railways, naval vessels and in the oil and gas industry.

Given the popularity of the Makila aviation turboshaft engine, the offering of an Industrial and Marine (I&M) variant, also known as the TM-1600 (TM-1600 I&M), was considered to be a natural, especially considering the synergy of the two programs and the wide customer base of the aero engine. Since its introduction, the TM-1600 I&M/Makila TI has made a rapid penetration

into the 50 Hz and 60 Hz power generation/cogeneration arena, an arena that should remain vibrant for quite some time.

TM-1600 Packaged Design Versions. Three packaged design versions of the TM-1600 I&M (formerly called Makila TI) are available, as follows:

Standard Versions. These machines serve as centrifugal pump drives for water injection and turbo-pump fire fighting applications, and as propulsion units for high-speed trains and surface vessels/fast boats. The output shaft speed with an integral reduction gearbox ranges from 4,000 rpm to 6,000 rpm.

Direct Drive Versions. These machines serve as high-speed centrifugal compressor drives for gas gathering and gas pipeline boosting, and as direct output prime movers for high-speed drive applications. Output shaft speeds range from 14,000 rpm to 23,000 rpm.

Power Drive Versions. These machines serve as an electric generator drive for base load power generation or peaking and for cogeneration plants, as well as for reciprocating compressor drive for gas lift and gas injection. The output shaft speed with an integral reduction gearbox ranges from 1,000 rpm to 3,000 rpm.

In a genset role, the TM-1600 I&M has a power output of 1,050 kW (ISO conditions). Approximate genset dimensions are as follows:

	<u>Metric Units</u>	<u>English Units</u>
Length	5.9 meters	19.35 feet
Width	1.8 meters	5.9 feet
Height	2.15 meters	7.05 feet
Weight	9,000 kg	19,841 pounds

TM-1600 I&M Applications. Among the current or projected applications of the TM-1600 I&M/Makila TI machine are the following:

Train Propulsion. Part of the first production batch of TM-1600 I&M/Makila TI engines is for a train propulsion application in France, for a French Railway turbotrain. The engines are nominally rated at 1,200

kW ISO continuous, burning distillate fuel, and were shipped in late 1988.

Cogeneration. Cogeneration is usually achieved by heating water and is suitable for a wide variety of industrial or tertiary sectors to achieve production of heat for industrial processes, space heating, air conditioning (absorption units), district heating, hot domestic water and heating of swimming pools.

According to Turbomeca, data pertaining to the TM-1600 I&M versions are as follows:

<u>Parameter</u>	<u>Recovery without Supplemental Firing</u>	<u>Recovery with Combustion at 1,000°C</u>
Hot Water Flow with Temperature Raised: + 20°C	95,000 kg/h	217,000 kg/h
Production of Saturated 4 kg/cm ²	3,300 kg/h	5,850 kg/h
Fuel Consumption	4,120 kWhr/h	7,080 kWhr/h

Part of the first batch of production machines were for an industrial cogeneration facility in Japan, where the gas turbine will be used with an unfired waste heat recovery boiler. The gas turbine produces 6,000 lb/hr (2,721 kg/h) of steam at 1,200 kPa, burning natural gas. Machines for that role were shipped in late 1988.

Mechanical Drive. TM-1600 I&M/Makila TI machines are used for various mechanical drivers, and are packaged by IHI in Japan.

Marine Propulsion. The TM-1600 I&M/Makila TI is used in marine propulsion; it features corrosion-resistant materials to withstand the marine environment. The engine is offered for both main propulsion and shipboard power generation duties and can be arranged in both twin-shaft and single-shaft configurations.

The TM-1600 was selected as the powerplant for Arnold Transit Company's (Mackinac Island, MI)

\$3 million vessel *Straits Express*, a 99-foot (30.17-meter) catamaran capable of carrying 400 passengers at 38 knots (70.4 km/h). The vessel, built by Marinette Marine Corp (Marinette, WI), is powered by two TM-1600s (burning No. 2 diesel fuel), with ZF BW 465 marine gears and two Wadsworth Water Jet Model 3000 waterjets.

Allen Industries furnished all auxiliary equipment for the engines, including batteries, inlet filters, output flanges and final reduction gear. It worked with Wadsworth on adapting the propulsion system "from the gearbox back."

Allen's estimates are that the time between engine overhauls is about 15,000 hours; that amount compares favorably to the 5,000-hour overhaul schedule typical for diesel engines.

Funding

Funding specifically pertaining to the TM-1600 I&M/Makila TI has not been identified. It is unknown if Turbomeca used any outside finding or resources in the development of the TM-1600 I&M.

Recent Contracts

No major identifiable military contracts specifically pertaining to the Industrial/Marine Makila TI have been awarded or received in the recent past.

Recent Activity. Among the more notable events in the recent past with reference to the I&M Makila TI are the following:

Marine Application in the US. A fast ferry powered by a pair of TM-1600s began plying the US Great Lakes in the spring of 1995 (see above).

IHI Becomes Packager. Ishikawajima-Harima Heavy Industries (IHI), Tokyo, Japan, became a TM-1600 I&M/Makila TI packager in late 1989. The Japanese firm undertook the responsibility of selling the TI to the Japanese market.

At least three TM-1600 I&M machines have been sold in Japan, all for gas pumping service. IHI began the installation of those machines in 1990, for Tokyo Gas Company, Toho Gas Company and Osaka Gas Company.

Timetable

Among the major events in the TM-1600 I&M/Makila TI program are the following:

<u>Month</u>	<u>Year</u>	<u>Major Development</u>
Apr	1988	Makila TI program officially unveiled
Sep	1988	First Makila TI installed for Rail Propulsion/Power
Nov	1988	First Makila TI in cogeneration role installed
Early	1989	First European sale of TI
Late	1989	IHI becomes TI packager; IHI TI package design completed
Nov	1989	First European machine becomes operational
Q1	1991	Start of installation of IHI TI packages
Late	1992	PEMEX order for Makila TI-based turbopumps announced
	1993	TM-1600 ordered for use in UK hospital
	1995	TM-1600s ordered for marine propulsion duty
Thru	2009	Continued production/after-market support of TM-1600 I&M projected

Worldwide Distribution

As of the end of 2000, an estimated 100 TM-1600 I&M/Makila TI machines are projected to have been built (excluding units for rail propulsion). Customer nations include **France, Germany, Italy, Japan, Mexico, Spain, the UK** and the **US**.

Forecast Rationale

In the electrical generation arena, the Turbomeca TM-1600 I&M should continue to garner orders for just a few machines for installation in cogeneration and combined heat and power applications – with or without supplementary firing in a water heat recovery boiler. Those cogeneration sets will likely be installed in paper mills, chemical plants, breweries and similar, smaller industrial facilities.

The strongest application arena projected for the TM-1600 I&M for the 10-year forecast period is mechanical drives. Thanks to the high crude oil prices, construction of pipelines of all diameters is ongoing, and Turbomeca continues to offer its machines for pumps and compressor drives, especially in the Middle East, in the formerly Soviet countries around the Caspian Sea, and possibly in South America.

We project that over the next ten years, orders for the TM-1600 I&M for all applications should translate into

the production of 33 machines. Turbomeca is expected to produce nine for generation applications, six for marine propulsion (mainly fast ferries and large yachts), and 18 machines for mechanical drive applications (pipeline and process industries).

It should be noted here that Turbomeca continues to actively work on the Eurodyn project with Volvo and Ulstein. That machine has a power output in the range of 2.5-3.0 MW, and has a high efficiency rating. We feel that that machine will dramatically eat into the markets of the TM-1600 I&M. Production of the Eurodyn machine should jump from 8-10 in 2001 to over 30 machines per year in the post-2006 period.

While Turbomeca will be sorry about the demise of the TM-1600 I&M, we are certain that it will be quite happy about the rosy future of the Eurodyn.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

Engine	(Application)	thru 99	High Confidence Level			Good Confidence Level			Speculative			Total 00-09	
			00	01	02	03	04	05	06	07	08		09
TURBOMECA													
TM-1600 I&M (a)	GENERATION	67	3	4	2	0	0	0	0	0	0	0	9
TM-1600 I&M	MARINE PROPULSION	17	0	2	0	2	2	0	0	0	0	0	6
TM-1600 I&M (a)	MECHANICAL DRIVE	11	2	2	4	3	3	3	1	0	0	0	18
Total Production		95	5	8	6	5	5	3	1	0	0	0	33

(a) Production includes machines shipped to IHI for use in IHI packaged units.